Women achieve peak swim performance in individual medley at earlier ages than men

Buhl, C ; Knechtle, B ; Rüst, C A ; Rosemann, T ; Lepers, R

Abstract: Introduction: Previous studies suggested that the age of peak swim performance in freestyle swimming was 17 years for women and 19 years for men. However, no study investigated the age of peak swim performance in other disciplines such as individual medley. Objective: To examine the change in the age of peak individual medley performance for both elite female and male Swiss swimmers from 1994 to 2011. Methods: The change in age of peak individual medley performance was investigated for elite female and male swimmers from 1994 to 2011. For comparison, an analysis of freestyle swimming was also performed. Swim speed in 200m and 400m medley, sex and age of the top ten swimmers at national level (Switzerland) were analysed using linear regression and two-way analysis of variance (ANOVA). Results: The age of peak swim speed was ($P < 0.01$) higher for men than for women in 200m medley (21.1 ± 1.0 vs 18.2 ± 0.8 years) and in 200m freestyle (21.4 ± 0.9 vs 19.3 ± 1.0 years). The age of peak swim speed was ($P < 0.01$) higher for men than for women in 400m medley (20.8 ± 0.4 vs 18.6 ± 0.7 years) and in 400m freestyle (20.3 ± 1.0 vs 18.6 ± 1.5 years). The age of peak swim speed remained unchanged across years for both medley and freestyle ($P > 0.05$). Swim performances improved for both swim styles and distances across years (P 0.03). Conclusion: The age of peak swim performance in medley and freestyle remained stable and was lower for women than for men in elite Swiss swimmers during the 1994 to 2011 period. Future studies need to investigate the age of peak swim speed in swimmers at international level in other competitive swim strokes. Key words: swim performance, gender difference, individual medley, freestyle

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WOMEN ACHIEVE PEAK SWIM PERFORMANCE IN INDIVIDUAL MEDLEY AT EARLIER AGES THAN MEN

Christof Buhl[1 (B,E,F)], Beat Knechtle[1,2 (A,D)], Christoph Alexander Rüst[1 (A,C)], Thomas Rosemann[1 (D,E)], Romuald Lepers[3 (A,D,E)]

[1]Institute of General Practice and for Health Services Research, University of Zurich, Zurich, Switzerland
[2]Gesundheitszentrum St. Gallen, St. Gallen, Switzerland
[3]INSERM U1093, Faculty of Sport Sciences, University of Burgundy, Dijon, France

Abstract

Introduction: Previous studies suggested that the age of peak swim performance in freestyle swimming was ~17 years for women and ~19 years for men. However, no study investigated the age of peak swim performance in other disciplines such as individual medley.

Objective: To examine the change in the age of peak individual medley performance for both elite female and male Swiss swimmers from 1994 to 2011.

Methods: The change in age of peak individual medley performance was investigated for elite female and male swimmers from 1994 to 2011. For comparison, an analysis of freestyle swimming was also performed. Swim speed in 200m and 400m medley, sex and age of the top ten swimmers at national level (Switzerland) were analysed using linear regression and two-way analysis of variance (ANOVA).

Results: The age of peak swim speed was ($P < 0.01$) higher for men than for women in 200m medley (21.1 ± 1.0 *vs* 18.2 ± 0.8 years) and in 200m freestyle (21.4 ± 0.9 *vs* 19.3 ± 1.0 years). The age of peak swim speed was ($P < 0.01$) higher for men than for women in 400m medley (20.8 ± 0.4 *vs* 18.6 ± 0.7 years) and in 400m freestyle (20.3 ± 1.0 *vs* 18.6 ± 1.5 years). The age of peak swim speed remained unchanged across years for both medley and freestyle ($P > 0.05$). Swim performances improved for both swim styles and distances across years ($P \leq 0.03$).

Conclusion: The age of peak swim performance in medley and freestyle remained stable and was lower for women than for men in elite Swiss swimmers during the 1994 to 2011 period. Future studies need to investigate the age of peak swim speed in swimmers at international level in other competitive swim strokes.

Key words: *swim performance, gender difference, individual medley, freestyle*

Introduction

Recent studies showed that endurance performance decreased with increasing age [1-3]. In endurance athletes, a peak in performance was described at the age of 35 to 40 years with a continuous decrease in performance until the age of ~70 years [2,4], afterwards followed by an exponentially decrease [1-3].

From the perspective of coaches and athletes not only the age-related performance decline but rather the age of peak performance might be even more of interest in order to estimate when endurance performance starts to decrease. The age of peak performance has been investigated in different sports disciplines such as running [5-8] and triathlon [9,10].

Contrary to running, the age of peak swim speed was barely investigated and only for freestyle swimming [2,8,11]. The relationship between age and the length of the race distance seemed to be reversed in running compared to swimming, where longer swim distances were associated with younger ages [8,11]. For long course pool freestyle swimming, the fastest 1,500m freestyle times were achieved at a younger age of ~18.4 years compared to the fastest 50m swim times at ~23.1 years [11]. An analysis of Olympic swimming data from 1896 to 1980 revealed that also the sex seemed to have an influence on the age of peak swim speed since women generally achieved peak swim speed at younger ages than men [8]. Schulz and Curnow analyzed men's 100m, 400m and 1,500m freestyle and women's 100m, 400m and 800m freestyle, respectively, and separated their data into two halves (1896-1936 and 1942-1980, respectively) using World War II as a dividing point [8]. For men, the age of peak swim speed decreased in the 100m freestyle from 22.0 years between 1896 and 1936 to 20.8 years between 1942 and 1980, and the 400m freestyle from 20.4 years to 19.4 years, respectively. For women, however, the age of peak swim speed increased in the 100m freestyle from 18 years to 20.3 years, but decreased in the 400m freestyle from 18 years to 17.3 years during the period of the study.

The data from Schulz and Curnow showed that women were younger than men at the age of peak swim speed and that the age of peak swim speed decreased across years from 1896 to 1980 [8]. However, newer data after 1980 are lacking and it would be interesting to investigate the trend in the last 30 years. Also, Schulz and Curnow did not include the 200m freestyle for both sexes, the 1,500m for women and the 800m for

men in their analyses [8]. The age-related decline in swim speed and the age of peak swim speed has been investigated for swimmers in freestyle swimming from the 50m to the 1,500m distance [2,3,8], but not for other swim styles such as individual medley. Individual medley is the combination of butterfly, backstroke, breaststroke, and freestyle within one race and has to be completed in the listed order [12]. The competitions are held over the 200m and 400m distance in the 50m long course pool, as well as additional over the 100m distance in the 25m short course pool [13].

The aim of the present study was to examine the change in the age of peak individual medley performance for both elite female and male Swiss swimmers from 1994 to 2011. Existing literature investigated to the best of our knowledge only the age of peak swim speed in freestyle swimming [2,8,11]. In order to enhance a better comparison with the literature, an analysis of freestyle swimming was also performed. Based upon existing literature, we hypothesized that (*i*) the age of peak swim speed would be younger for women compared to men for both the 200m and the 400m individual medley and (*ii*) the age of peak swim speed would still decrease from 1980 to 2011. To test these hypotheses, we analyzed the results of the high score list of Swiss top swimmers from 1984 to 2011 and compared the age of the top ten swimmers across years for both sexes in 200m and 400m individual medley and freestyle.

Methods

The study was approved by the Institutional Review Board of St. Gallen, Switzerland, with waiver of the requirement for informed consent given that the study involved the analysis of publicly available data. The data set from this study was obtained from the website of the Swiss Swimming Federation (http://rankings.fsn.ch/).

Data sampling and data analysis

Top ten freestyle and individual medley swimmers from the Swiss swimming high score list between 1984 and 2011 on 50m long course were analysed in the 200m and 400m distance regarding swim times, sex and age. In total, data were available from 1984 to 2011 for 207,852 athletes, including 102,213 women and 105,639 men. Due to the low annual number of swimmers per distance between 1984 and 1993, we decided to investigate only swimmers between 1994 and 2011, leading to a total number of 204,961 swimmers, including 100,693 women and 104,268 men. We present the change across years of the mean age of the annual top ten swimmers, separately for both the 200m and the 400m individual medley and freestyle, respectively. Afterwards, these data were analysed regarding differences in age between sexes as well as development of the yearly age of the fastest swim time during time. Results were transformed to speed values using the equation [swim distance in meters] / [swim time in seconds]. No athlete was included twice or several times in the same year because Swiss Swimming Federation lists only the best swim time per year of an athlete in the same year.

Statistical analysis

In order to increase the reliability of data analyses, each set of data was tested for normal distribution as well as for homogeneity of variances in advance of statistical analyses. Normal distribution was tested using a D'Agostino and Pearson omnibus normality test and homogeneity of variances was tested using a Levene's test. Linear regression was used to find significant changes in a variable across years. Two-way ANOVA was used to analyze differences between top ten women and men year by year and to find interactions between different variables affecting performance (sex × distance in different swim styles and sex × style in different distances regarding overall performance; sex × years in different swim styles and distances). Statistical analyses were performed using IBM SPSS Statistics (Version 19, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 5, GraphPad Software, La Jolla, CA, USA). Significance was accepted at $P < 0.05$ (two-sided for *t*-tests). Data in the text are given as mean ± standard deviation (SD).

Results

For 200m individual medley, the age of peak swim performance remained unchanged across years (Fig. 1, Panel A). The age of peak swim performance for 200m medley was younger for women than men ($P < 0.01$) (Table 1). Similarly, for the 400m, the age of peak

Table 1. *Mean (±SD) age of peak swim performance for women and men*

Mean age of peak swim speed	Individual Medley		Freestyle	
	200m	400m	200m	400m
Women	18.2±0.8	18.6±0.7	19.3±1.0	18.6±1.5
Men	21.1±1.0	20.8±0.4	21.4±0.9	20.3±1.0
	**	**	**	**

** = Significant difference between women and men, $P < 0.01$

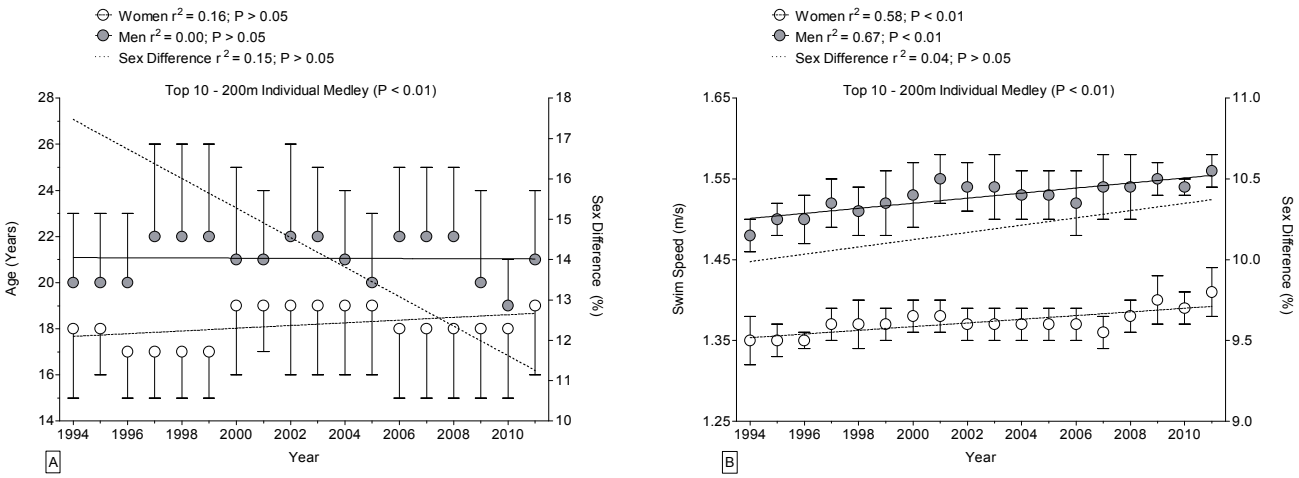

Fig. 1. *Change in age (Panel A) and swim speed (Panel B) of the top ten individual medley swimmers for 200m with sex difference from 1994 to 2011*

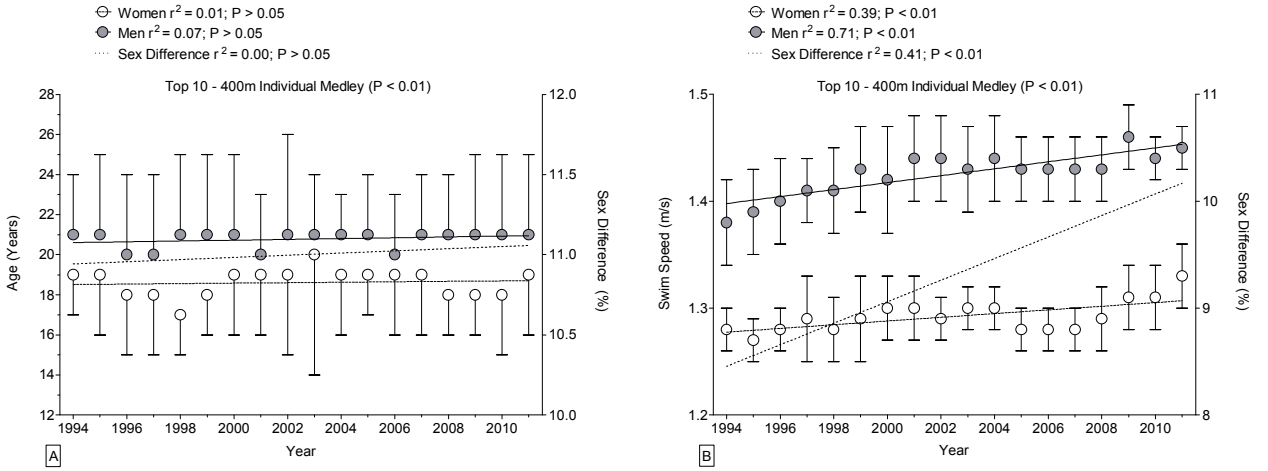

Fig. 2. *Change in age (Panel A) and swim speed (Panel B) of the top ten individual medley swimmers for 400m with sex difference from 1994 to 2011*

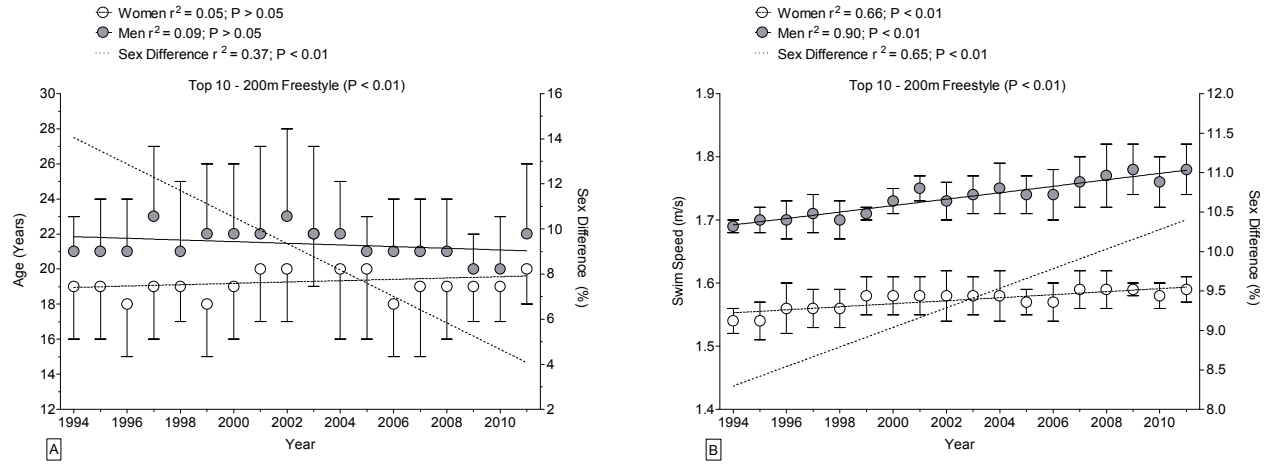

Fig. 3. *Change in age (Panel A) and swim speed (Panel B) of the top ten freestyle swimmers for 200m with sex difference from 1994 to 2011*

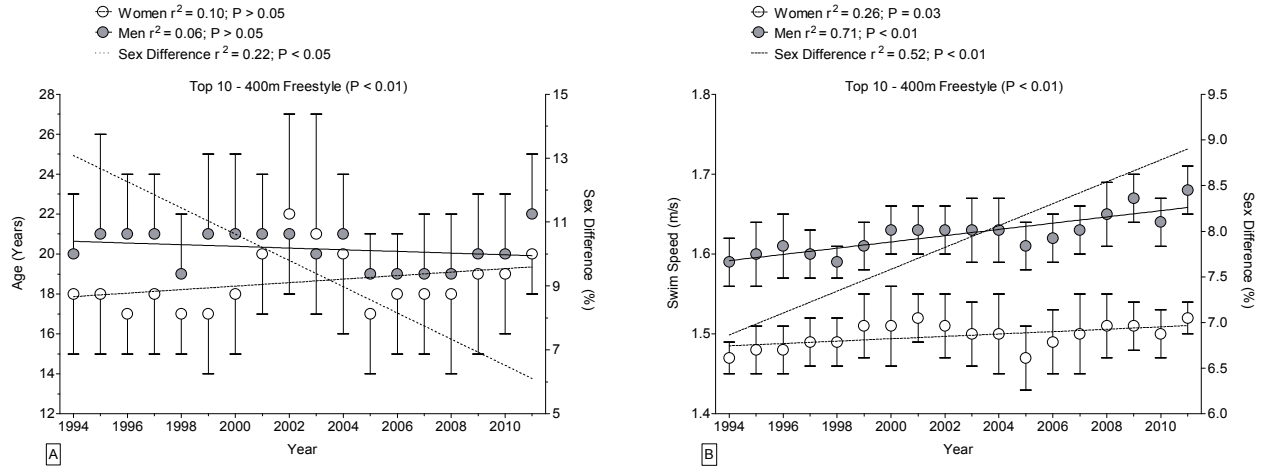

Fig. 4. *Change in age (Panel A) and swim speed (Panel B) of the top ten freestyle swimmers for 400m with sex difference from 1994 to 2011*

swim performance remained unchanged across years (Fig. 2, Panel A). The age of peak swim performance for 400m medley was younger for women than men ($P < 0.01$) (Table 1).

In the 200m freestyle, the age of peak swim performance remained unchanged across years (Fig. 3, Panel A). The age of peak swim performance for 200m freestyle was younger for women than men ($P < 0.01$) (Table 1). Similarly, for the 400m, the age of peak swim speed remained unchanged across years (Fig. 4, Panel A). The age of peak swim performance for 400m freestyle was younger for women than men ($P < 0.01$) (Table 1).

Swim performances improved for both swim styles and distances during the 1994 to 2011 period ($P \leq 0.03$) (Fig. 1-3, Panel B). In both individual medley and freestyle, a highly significant ($P < 0.001$) interaction between sex and distance on swim speed was observed. In individual medley, the interaction accounted for 81.3% ($F = 630.7$; $P < 0.001$) of the total variance, whereas sex and distance accounted both for 4.9% ($F = 38.3$; $P < 0.001$). In freestyle, the interaction accounted for 1% ($F = 12.1$; $P < 0.001$) of the total variance, whereas sex accounted for 27.2% ($F = 322.8$; $P < 0.001$) and distance accounted for 66.1% ($F = 784.6$; $P < 0.001$) of the total variance. There was no significant interaction between sex and swim style for the 200m and the 400m and no significant interaction between sex and time (years) for freestyle and individual medley.

Discussion

The main findings of this study were (*i*) women achieved their peak swim speed at a younger age than men for both medley and freestyle, at 200m and 400m, during the 1994-2011 period, and (*ii*) the age of peak swim speed remained unchanged between 1994 and 2011.

The major finding was that women achieved their peak swim speed at a younger age than men in both medley and freestyle. The age of peak swim speed was around 20-21 years for men and around two and three years earlier for women. The age of peak swim speed in freestyle and medley seemed to be close together in a range of ~0.5 years, apart from women in the 200m, where the age was 1.1 years younger for medley than for freestyle. Thus, the age of peak swim speed was approximately comparable in individual medley and freestyle.

Our findings are in line with the findings of Schulz and Curnow [8], investigating Olympic Gold medalists between 1886 and 1980. During that period, however, the mean age of peak swim speed was ~17 years in women and ~19 years in men, respectively. An explanation for the differences between women and men could be anthropometric characteristics such as body fat as an important predictor variable for swimming performance [14-16]. A further study showed that the gain of fat mass is precisely during puberty different in boys and girls [17]. Zuniga *et al.* reported for sprint swimmers that ~11 year old boys had with ~9.4% lower percent body fat than girls with ~12.7% [16]. Tuuri *et al.* showed that a greater fat mass in women was more strongly related to lower levels of exercise performance in swimmers [15]. Bitar *et al.* reported that during the onset of puberty, boys and girls gained fat-free mass, whereas fat mass gain was higher in girls [17]. Lean body mass, which primarily reflects muscle mass, begins to increase during early puberty in both sexes. Fat mass, however, increases during the late stages of puberty in girls [18]. A further increase in fat mass after puberty may impair swim performance in women. Furthermore, maturation is earlier in women than in men [18,19]. This can be seen in bone growth during puberty in relation to physical growth [20]. Maximal increase of all bone variables occurred earlier in girls than in boys. By the age of 17, boys had attained ~86% of the reference adult bone mineral content and volumetric density, while girls had attained ~93-94%.

An actual study on growth of the metacarpal bones showed a ~2 year difference in the growth pattern between boys and girls [19].

The second major finding was that the age of peak swim speed in individual medley and freestyle remained unchanged between 1994 and 2011. During the studied period, swim performances improved for both swim styles and distances. Different studies investigated predictor variables determine swimming performance [21-24]. There were found correlations between performance and horizontal jump, grip strength, shoulder flexibility [22] and upper extremity length [21,22]. Another study showed correlation between women's swimming performance and height, percent body fat and fat-free weight in competitive collegiate swimmers [14]. Furthermore, a recent study showed in elite master swimmers of both sexes that age and height were best predictors in swimming events [24]. Kagawa et al. analysed the changes during the 20th century in Japanese children from the age of 6 to 17 years [25]. Boys had increments of 1.0-2.0 cm and 0.4-1.7 kg per decade whereas girls had rates of 1.1-1.9 cm and 0.4-1.5 kg per decade, respectively. However, there seems to be a levelling-off of the body height and weight. An investigation of Polish children and adolescents between 1880 and 2000 showed changes in height and body weight. Accelerated physical development between the 1950s and the 1980s was followed by a tendency towards deceleration in the last decade [26].

Schulz and Curnow reported a decrease in the age of peak performance in the 400m freestyle for men from 20.4 years between 1896 and 1936 to 19.4 years between 1942 and 1980, and for women, from 18 years to 17.3 years [8]. While Schulz and Curnow investigated the period between 1896 and 1980 [8], we analyzed data from 1994 to 2011. Reasons for the disparate findings compared to the existing literature [8,11] might be explained by anthropometric characteristics predicting swimming performance, such as body height [21-24] and their changes across years [25,26].

A further finding was that the interaction between sex and distance had a significant impact on swim speed in individual medley and freestyle, whereas distance accounted for the higher fraction of variance than sex in freestyle. However neither the interaction between sex and stroke, nor the interaction between sex and time had an influence on swim speed.

Conclusions

Although swim performances improved during the 1994 to 2011 period, the age of peak performance in medley and freestyle remained stable and was younger for women than for men in elite Swiss swimmers. Future studies need to investigate the age of peak performance across years in the different strokes combined with changes in anthropometry, as well as changes in training models in swimmers at international level.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

CB carried out the data collection and drafted the manuscript. BK conceived and designed the study and revised the manuscript. CR carried out the statistical analysis. RL and TR participated in the coordination and revised the manuscript. All authors read and approved the final manuscript.

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Address for correspondence:
PD Dr. med. Beat Knechtle
Facharzt FMH für Allgemeinmedizin
Gesundheitszentrum St. Gallen
Vadianstrasse 26
9001 St. Gallen
Switzerland
Telefon +41 (0) 71 226 82 82
Telefax +41 (0) 71 226 82 72
e-mail: beat.knechtle@hispeed.ch

Christof Buhl: christofbuhl@gmx.ch
Christoph Rüst: christoph.ruest@bluewin.ch
Thomas Rosemann: thomas.rosemann@usz.ch
Romuald Lepers: romuald.lepers@u-bourgogne.fr